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ABSTRACT

This book provides five instructional units on groundwater. Units included are: (1) "Where's the Groundwater?" (describing the concepts of a saturated zone, water table, hydrologic cycle, recharge and discharge, core of depression, subsidence, and saltwater intrusion); (2) "How Does It Travel?" (discussing porosity, permeability, impermeability, sedimentary rock, crystalline rocks, faults, unconsolidated deposits, aquifer, and artesian well; (3) "What's in the Groundwater?" (discussing septic systems, toxic materials, leachates, landfills, hazardous waste sites, nitrates, and radioactive wastes); (4) "Virginia's Regions" (describing five main geologic regions); and (5) "What We Can Do to Help." The publication contains many diagrams, demonstrations, and a glossary. (YP)

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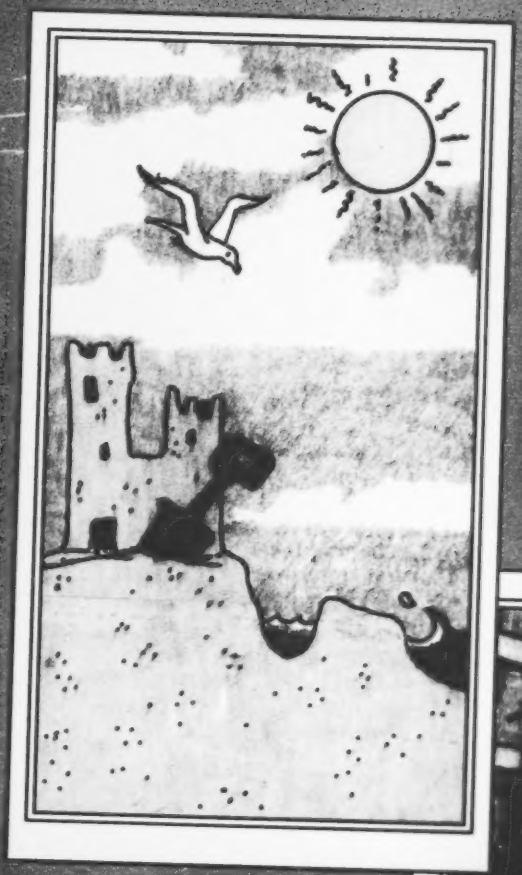

Sandcastle Moats

And Peanut Butter Holes

A book about groundwater

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Sandcastle Moats and Petunia Bed Holes

A book about groundwater

text by Pat Nickinson
illustrations by George V. Wills

demonstrations contributed by Bob Lamons

Virginia Water Resources Research Center
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

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Introduction

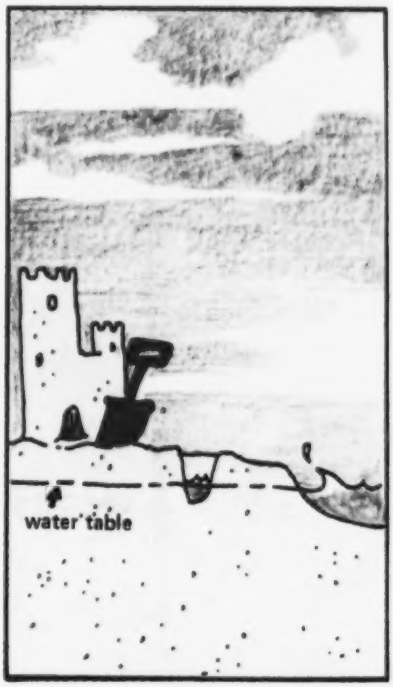
WHY YOU OUGHT TO READ THIS BOOK:

Remember when you were just a little kid at the beach and you dug a moat around your sandcastle and the deeper you dug, the more your moat filled with water EVEN THOUGH THE WAVES WEREN'T COMING ANYWHERE NEAR IT?

That's the first clue.

Here's the second one:

Remember how your next door neighbor yelled until her face turned red because your dog dug a hole in her petunias? Take a little closer look at this memory. Look at the dirt Rover excavated: it's just the slightest bit damp and cool (which is why Rover dug it up in the first place), BUT THERE ISN'T ANY WATER IN THE HOLE, EVEN THOUGH IT'S TWICE AS DEEP AS THE HOLE AROUND THE SAND CASTLE.



Why was there water in the moat but not in the petunia hole?

Whether you reach water depends on how deep the WATER TABLE is where you're digging.

groundwater

WHY YOU OUGHT TO KNOW ABOUT WATER TABLES:

How else are you going to know where to put a well?

Okay, so you may not really need to know where to put a well. But IF you figure out enough of this book to choose a good well site, then you'll also know enough to take care of the GROUNDWATER (that's the water under the earth's surface) we depend on here in Virginia.

AND WHY, YOU MIGHT ASK, SHOULD WE TAKE CARE OF THE GROUNDWATER?

Well, that depends. How much do you like being able to turn on the faucet to get a drink? How much do you like having an indoor bathroom instead of an outhouse? How much do you like being able to take a shower when you're dirty?

You knew there wasn't going to be an easy answer, didn't you?

If we're going to have clean water for all those things we've gotten used to, we have to know enough about our water to take care of it. And because a lot of the water we use in Virginia comes from underground, we need to know what the underground water has been up to — and what we have done to it — before we take it out to use it.

How are you going to take care of something you can't even find???

Knowing about groundwater is important in Virginia. More than a million and a half Virginians get all their water from wells or springs. Many of our industries, farms, and electric plants need well water, too.

Even metropolitan systems that get their water mostly from surface waters like rivers sometimes use some groundwater, too. Groundwater comes out of wells — and other places, like springs.

In fact, in most places under the surface, there's at least some groundwater. The questions are: Where? How deep? Can you get it out? And is it drinkable?

Ready to start? First you have to find the water table. But before you can do that, you have to know what a water table is.

Unit 1: Where's the Groundwater?

The question is: where's the groundwater? First you have to find the water table.

TO MAKE A WATER TABLE:

If you fill a clear plastic cup with some small gravel then pour in a couple ounces of water, you'll see the water drip down through the gravel until most of it ends up in the bottom of the cup. The gravel flooded with water is called the SATURATED ZONE because the gravel is saturated with water — all the spaces between the chunks are filled.

saturated zone

In the upper layer, water "sticks" to the surface of the gravel chunks, but the spaces between are filled with air rather than water. The top layer is called the UNSATURATED ZONE. (Sometimes it is called the zone of aeration; "aer" is pronounced just like "air": that tells you what fills the spaces between the pieces of gravel in the unsaturated zone.)

unsaturated zone

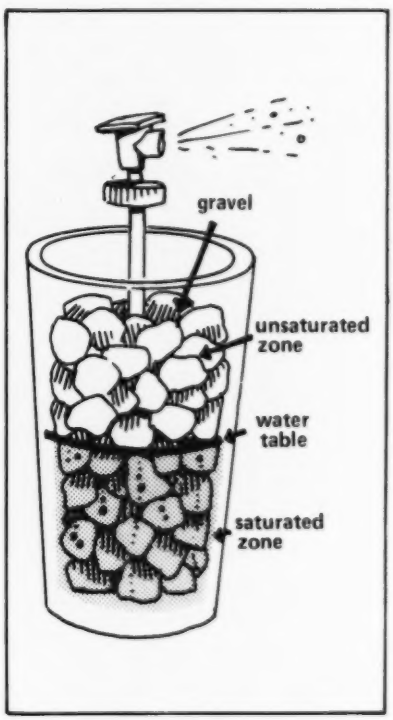
THE WATER TABLE IS THE TOP SURFACE OF THE SATURATED ZONE. The water table separates the saturated zone from the unsaturated zone. And the saturated zone is where the groundwater is.

water table

Water moves in to fill any open spaces below the water table. If a well pumps out some of the water, nearby groundwater will move in to fill the spaces.

But how did groundwater get in the well in the first place?

When you put a soda straw into a cup of cola and ice, the cola will fill the straw below the "water table." The soda straw was like an open space in the cola's "saturated zone." If you suck some of the cola out of the straw, the cola outside the straw flows through the ice chunks into the straw, to replace the cola you drank. If you wait between sips, you can watch the soda fill the straw (below the water table) again.



A well works along the same lines.

A well, like a soda straw, leaves an open space for liquid to flow into. In the ground, a well acts like an open space in the saturated zone. Water from the surrounding rocks will keep on flowing into that "open space" as long as the water table is higher than the well's intake area.

You can demonstrate this by putting a spray pump into the cup of gravel below the "water table." Each time you pump water out of the well, you leave space for the surrounding water to flow into.

A well is one way groundwater comes out of the earth. There are lots

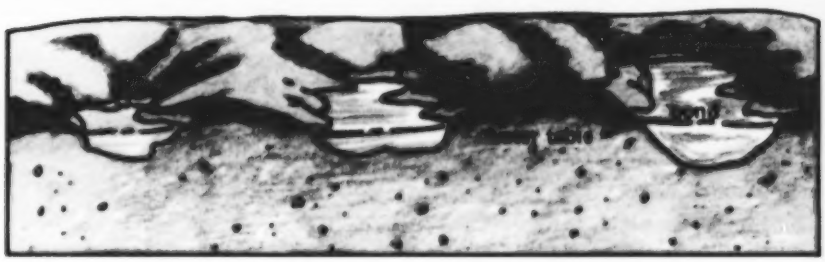
of others. When you see a spring bubbling out of a hillside, that's groundwater coming out. Ponds and lakes may be fed by groundwater. Geysers are groundwater, too. When groundwater is heated and just has to let off a little steam, it becomes a geyser.

hydrologic cycle

Groundwater oozes out whenever the ground surface dips below (intersects) the water table — sometimes through springs or into ponds, sometimes into creeks and rivers, sometimes directly into the ocean. By then it's surface water, and it's ready to start the HYDROLOGIC CYCLE all over, evaporating into the atmosphere to become rain or snow once again.

What comes out must have gone in . . . somewhere.

When rainfall or melting snow soaks into the ground, the water percolates down



Land surfaces dipping below the water table will create ponds or lakes.

WELLS

What image do you get when you think of a family well?

Maybe you picture an old fashioned well, the red brick kind with a little roof and a bucket you haul up on a rope.

That kind of well was usually dug by hand, using shovels and buckets until a hole in the ground hit water. The hole reached just into the saturated zone, like the sandcastle's moat in the introduction. To keep the sides from caving in, well owners lined them with stones, bricks, or wood. Pumps or buckets on ropes brought water up from the bottom of the well.

Today's wells don't look very much like those old ones.

Today's wells are drilled or "bored" by machines which hollow out a much deeper shaft through soil layers and rocks. Many new family wells are between 50 and 150 feet deep, although they may be a lot deeper.

The new wells are usually lined or "cased" with concrete, steel, or PVC (polyvinylchloride) pipe.

And they're more than just holes in the ground. Newer wells have all sorts of protective features to keep unwanted substances out of the well water. For instance, wells sunk into sand and gravel layers usually have a screen to keep grit out of the water.

The space between the drilled or bored hole and the casing is usually filled with a cement grout from the ground surface down at least 20 feet. (Grout is a thin mortar or some similar material which is used to fill spaces.) This grout helps to keep surface water (which may be contaminated) from flowing into the well.

Surface water is also diverted (turned away) from the well by sloping the ground surface away from the well.

And in areas where the water quality is not outstanding, wells may come equipped with their own chlorinators and water softeners to make the water usable.

through the soil and rocks until it reaches the saturated zone. Water just coming into the groundwater system is called RECHARGE. Surface water can be a source of recharge for groundwater, too. Water from a creek or lake can leak down through the soil toward the saturated zone —then it becomes groundwater, too.

recharge

Springs and geysers and well water — where water comes out of the ground — are called DISCHARGE. Recharge is water going in to the ground, discharge is water coming out.

discharge

If the water table is going to stay about the same level, then the water coming into the system (the recharge) must equal the amount of water going out of the system (the discharge).

Recharge adds water to the saturated zone. It replaces water that got pumped out or that seeped out or that moved downward to lower levels.

Here's the first trick: although groundwater doesn't move very fast, water in the saturated zone almost never sits still. Gravity is always tugging at it, pulling it down through soil and rock layers toward any low point in the water table.

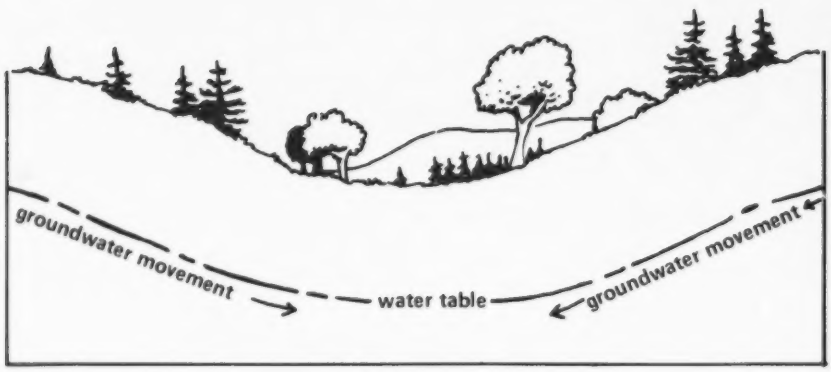
The continuous cycling of water through the earth and its atmosphere is known as the hydrologic cycle.

Among possible groundwater discharge locations are springs, streams, and oceans.

That's the second trick: the water table is almost never level. The water table often mimics the ground surface above it, so the water table has "hills" and "valleys" in it, too.

Where the ground surface dips (like a valley), the water table will often dip, too. But the water table can have valleys for other reasons. The water table around a well, for instance, will dip in a cone-shaped "valley."

Remember the spray pump in the cup of gravel and water? As you pump water out, the water table falls. It falls more rapidly around the well than it does farther away from the well because that's where the well is pumping water out, and the replacement water cannot move in as quickly as the well water is withdrawn.



Groundwater, like surface water, will flow "downhill."

HYDROLOGIC CYCLE

Recycling isn't anything new. The water (and all other matter) on earth has been recycled for millions and millions of years.

There's no telling where the water you use today was 1000 years ago. Or a million years ago. Or 300 million years ago. Someone once observed that the water coming out of our faucets today may have been part of a pool that a dinosaur drank from. It may have been hauled out of a well hundreds of years ago. It may have flowed down a river or been part of a vast ocean.

Water is recycled through what we call the "hydrologic cycle." Hydrology comes from Latin roots: "Hydro" meaning water and "logia," science of. It's a continuous cycle, so there isn't really a starting point. But let's start with rain anyway.

When moisture in the atmosphere condenses and falls to the earth as snow or rain, we call it "precipitation."

Some of the rain or snow will soak into the earth. That's what becomes groundwater. What doesn't soak in either "runs off" and joins creeks and rivers or oceans, or evaporates back into the atmosphere.

Some of the rain is used by growing plants. Plants then give off moisture which is evaporated back into the atmosphere. That's called "transpiration."

The groundwater the plants didn't use flows through the earth until it comes back out to the surface in springs or wells or creeks or lakes or whatever. Then it is surface water which flows to the ocean and also gradually evaporates back to the atmosphere.

When water has transpired or evaporated into the atmosphere, it can condense and — we have RAIN! ready to cycle through again and again and again and again and. . .well, you get the picture.

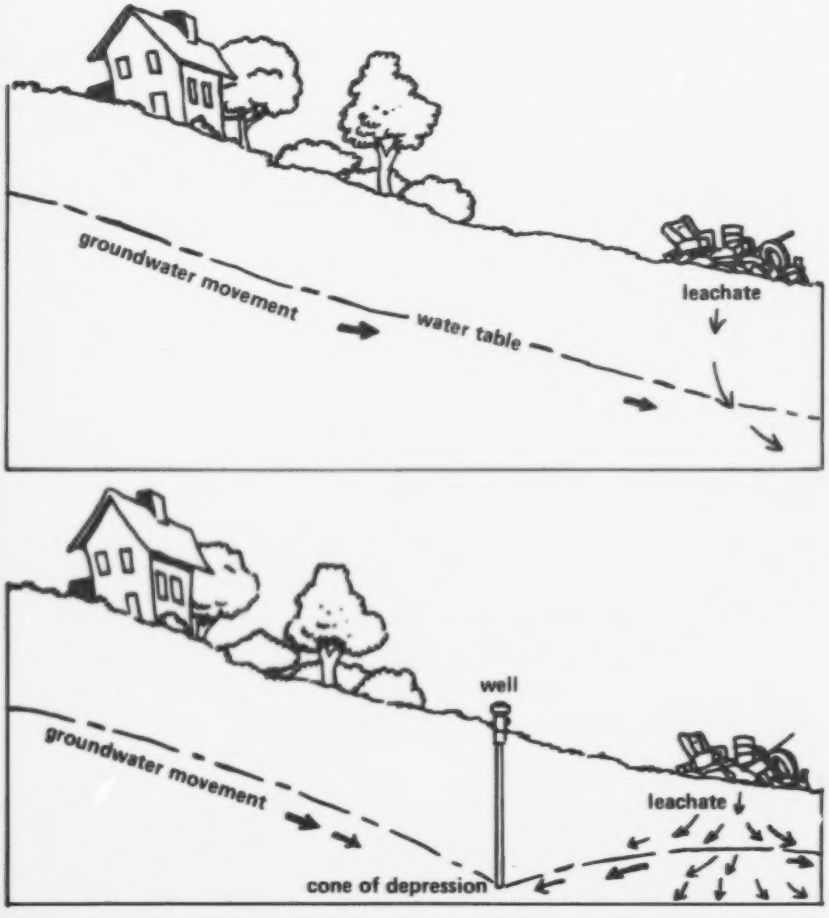
The farther away you get from the well, the less effect the pumping has on the level of the water table. It's a gradual change, so the water table level around a well has a sort of cone shape. That is called the CONE OF DEPRESSION.

cone of depression

This cone of depression is one of the "valleys" in the water table. Cones of depression are important for a couple reasons.

Because water flows down to lower points, the cone of depression could change the direction groundwater flows in. That might change what you find IN your well water; if there's a source of pollution near your well, the cone of depression might affect whether the pollution flows toward or away from the well. Cones of depression also can interfere with neighboring wells.

Changing the direction the groundwater moves isn't the only effect pumping may have on groundwater. If a well owner pumps water out faster than it can be replaced, the water table will drop and the well might run dry temporarily.



Groundwater generally follows flow paths dictated by gravity. A cone of depression around a well may influence high and low points in the water table, changing the direction of the water movement.

overwithdrawal

Pumping out too much water is called OVERWITHDRAWAL. In some areas, overwithdrawal can have some very startling effects: the ground might sink.

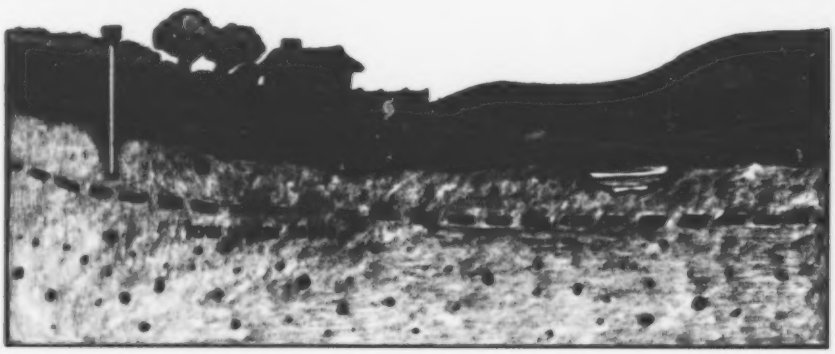
subsidence

Groundwater pressure helps support the ground. If too much water is pumped out, the pressure drops and the land sinks. This is called SUBSIDENCE. Mexico City (Mexico) and Houston, Texas, are both several feet lower than they used to be because the residents have pumped out so much groundwater. Sinkholes several hundred feet across happen in the same way in Florida.

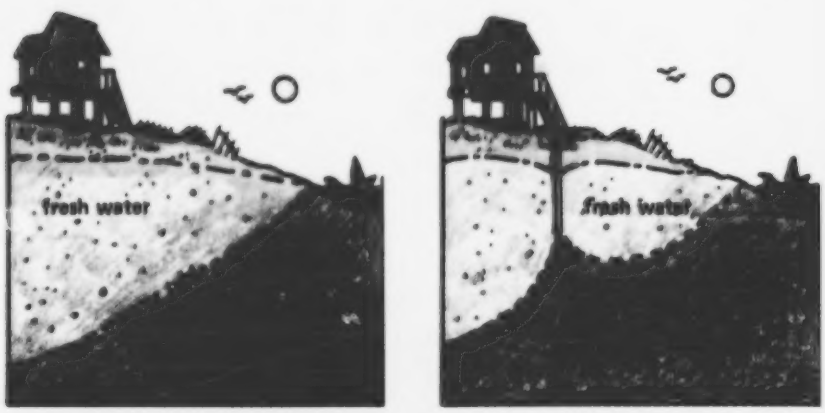
Coastal areas have another problem with overwithdrawal. Salt water isn't just in the ocean; it extends partway under the land, too. Remember the sandcastle moat? That was salt water filling the moat. A large wedge of the groundwater on the coast is salty. The farther inland you go, the more that salt water will be replaced by fresh (not salty) groundwater. The fresh water in the saturated zone "floats" above the salt water because the salt water is heavier (more dense).

saltwater intrusion

The problem occurs when people in coastal areas pump out too much of their fresh groundwater. The heavier salt water rushes in to fill the spaces. If the process continues, the salt water "intrudes" and wells may start pumping undrinkable (salty) water. The problem is called SALTWATER INTRUSION.



When the water table drops, ponds or streams may dry up and wells may run dry temporarily.



Overpumping of fresh groundwater near the coast allows heavier, denser saltwater to intrude; the problem is called saltwater intrusion.

Unit 2: How Does It Travel?

Humans may control how quickly groundwater is pumped out, but what controls how quickly groundwater moves INTO an area?

It's not just a matter of how much recharge (rainfall, snowmelt) the area gets, although that's important. It's also a question of how quickly the recharge water can move into and through the ground.

And that depends on what type of soils and rocks the water is moving through. If you dug up soil samples from different kinds of places — like a creek bank, a garden plot, the beach, the woods — you'd notice that the soils don't look alike. They don't act alike, either.

If you poured water through different soil types — such as sand, clay, gravel, and garden soil — you'd discover that water moves at different rates through different kinds of earth materials: quickly through the gravel and sand, more slowly through the garden soil, and most slowly of all through the clay.

Here's something else you ought to know: WATER MOVES THROUGH ROCKS the same way. Think back to the cup of gravel we used for the water table demonstration. Imagine the gravel as a close-up view of a single rock. The spaces between the chunks of gravel are like a rock's PORES. Pores are the spaces that water occupies when the rock (or a soil) is part of the saturated zone.

porous/porosity

Rocks with large pore spaces are called POROUS; that means that they can hold a great deal of water. How easily the water can travel through a rock depends on whether the pores are connected to each other.

Imagine a rock with bubbles trapped inside it. There are two possibilities. First, the rock might be full of bubbles, but the bubbles aren't connected to each other. Even if all the bubbles were filled with water, that water couldn't get out; it

DEMONSTRATION 1: POROSITY

PURPOSE: To gain an understanding of porosity

MATERIALS: 3 clear, hard plastic cups
marbles
sand
graduated cylinders
water

PROCEDURE: Fill one cup (to rim) with marbles, one cup (to rim) with sand, and a third cup (to rim) with a mixture of sand and marbles (pour in the marbles first, then add sand slowly while agitating the cup, to make sure sand filters down through the marbles). Measure and pour water into each cup until the water line reaches the rim of the cup. Record the amount of water used for each cup.

marbles: ____ cc water
sand: ____ cc water
marbles + sand: ____ cc water

CONCLUSION: The closer the fit of each particle to another, the smaller the space between them. As the spaces between the particles (the "pores") become smaller, the amount of water that can occupy that space is reduced. Both size and shape of a particle help to determine POROSITY, with mixed sizes having the smallest amount of pore space.

QUESTIONS:

1. What could the marbles represent?
2. How is the sand different from the marbles?
3. Which takes up more space in the cup, marbles or sand?
4. Which takes up more space, a marble or a grain of sand?
5. How do marbles and sand represent real ground or earth?
6. How are they different from real situations?

couldn't move THROUGH the rock. The second possibility: the bubbles ARE connected. Water could flow from bubble to bubble, in one side and out the other. Water could move through the rock as it could through a sponge.

permeability
impermeability

This second kind of rock, the one that water can move through, is called a PERMEABLE rock. Water is -ABLE to PERMEATE (move through). (A rock that water cannot move through is called IMPERMEABLE. The "im-" means "not.")

sedimentary rock

Water moves freely between the grains of sand in sandstone. Sandstone is called a SEDIMENTARY rock because it's made of compressed sediment (sand). Sedimentary rocks tend to be good places to look for groundwater.

DEMONSTRATION 2: PERMEABILITY

PURPOSE: To understand permeability (how easily water can move through a rock or soil)

MATERIALS: 8 plastic cups
clay
sand
gravel
soil
water
graduated cylinder
colored water
stopwatch

PROCEDURE: Punch four small holes in the bottom of each cup. Each cup will receive a different earth material or mixture of materials

cup 1: clay	cup 5: gravel + sand
cup 2: sand	cup 6: soil + gravel
cup 3: gravel	cup 7: soil + sand
cup 4: soil	cup 8: soil + gravel + sand

For each of the cups requiring a mixture (cups 5 - 8) use large containers to mix the materials thoroughly before you begin the next step.

Fill each cup with its required mixture (or plain material) so that the level of the earth material is 1" from the lip of the cup. Number each cup or label with mixture contained in each. Pour 25cc of water into each cup (if using very large cups, use 50cc water instead). (This first water will be drained and discarded; the purpose is to make sure all materials are saturated BEFORE timing how fast excess water — the second pouring — travels through. Otherwise "thirsty" earth materials will retain some of the timed water, and you won't get an accurate reading.)

Set the cups on pencils or matchsticks so the water can drain through the holes thoroughly. Wait 10 minutes.

This next part needs two people. One works the stopwatch and the other pours. With stopwatch ready, pour in 25cc of colored water. Start watch as soon as all the water has been poured in (quickly). Stop the watch when the first drop of colored water appears. Record times for each cup.

RESULTS:

clay = ____ seconds
sand = ____ seconds
gravel = ____ seconds
soil = ____ seconds
gravel + sand = ____ seconds
gravel + soil = ____ seconds
soil + sand = ____ seconds
soil + sand + gravel = ____ seconds

CONCLUSION: The different sizes and shapes of the particles create different sized pore spaces. The ease with which water passes through (permeability) in unconsolidated deposits like the ones in this demonstration is determined by the smallest of the gaps, as this is where water would start to back up. In a solid rock, however, water's ability to pass through depends on how well the pores are connected to each other.

QUESTIONS:

1. Which earth material was the most permeable? The least?
2. How did mixtures fare against single-material cups?
3. All of the earth materials used in this demonstration were "unconsolidated" so that permeability was a function almost entirely of the materials' porosity. How is this different from permeability in a solid rock?
4. The rate of water travel = soil distance divided by time travelled. Find the rate for each cup.

Limestone is also a sedimentary rock. Limestone isn't as porous as sandstone, but it is permeable; water moves easily through solution channels in the limestone's weak spots.

crystalline rock

Other rocks, like granite, have been partially melted by heat sources deep in the earth; when they cool and harden, they have hard, crystalline textures. (Sedimentary rocks, on the other hand, usually have "grainy" textures.) CRYSTALLINE rocks are made of tightly intergrown crystals. They don't have pore spaces.

fracture

Crystalline rocks can't soak up liquids because they don't have pore spaces. But they can HOLD and transport water — if there are FRACTURES (cracks) in the rock. And water can move from one fracture to another if the cracks meet. The more fractures, the more water the rock can hold.

fault

One special kind of rock fracture is called a FAULT. Suppose you have a massive (very large) piece of rock which gets fractured, say, by an earthquake. If a fracture splits the rock so that part of the rock moves upward while the other part moves downward (relative to each other), then the gap where the rock broke apart is called a fault. You may be able to see new, recently formed faults in ground where earthquakes have hit. On one side of a crack in the ground, the earth will be higher than on the other side.

What that has to do with groundwater is this: water can travel very, VERY easily through a fault. Instead of moving slowly through the pores or small cracks of a rock, now the water can just flow right between the pieces. Some mountainous areas in Virginia have ancient faults all through them.

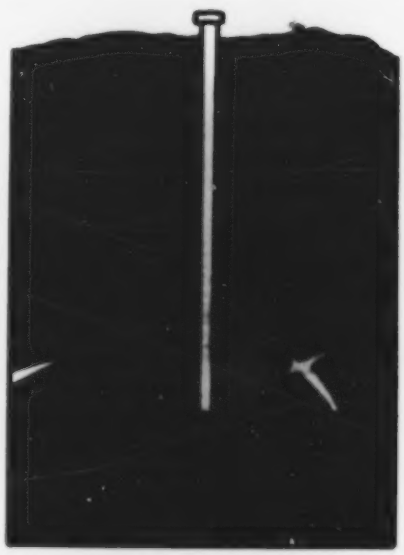
unconsolidated deposit

One last kind of earth material important to know about in connection with groundwater is called UNCONSOLIDATED. Sand and gravel deposits are unconsolidated ("not solid"); water flows right through them. They're called unconsolidated because the pieces are loose. Clay is also unconsolidated, but its pores are so tiny that water cannot pass through easily. Some clays are nearly impermeable.

Water can move through a rock layer only if the rock has connected pores or fractures — or both.

Groundwater in PERMEABLE soils and rock layers will move wherever gravity dictates (from high areas to low areas). But sometimes water reaches an IMPERMEABLE layer (a layer the water can't move through, like some clay beds). If the groundwater can't move through a layer, it may just collect on top of that layer.

If groundwater collects on top of an impermeable layer ABOVE the water table, it's called a PERCHED WATER TABLE. Usually perched water tables



Fractures can provide usable amounts of water.

perched water table

don't hold much water and they often dry up during dry seasons, so they aren't good places to put wells.

aquifer

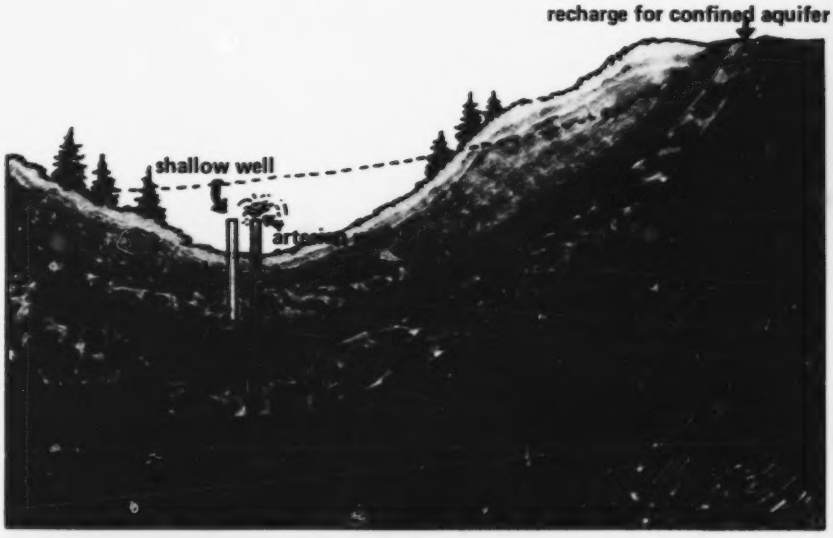
But let's assume that the groundwater makes it down to the water table. Whatever layer it collects in (and moves through) is called an AQUIFER. Aquifers can be sedimentary or crystalline rocks or unconsolidated deposits.

confined aquifer

Groundwater can be sandwiched between two layers of impermeable rocks. This groundwater sandwich is called a CONFINED AQUIFER.

The confined aquifer is like water running through a garden hose; if you punctured the hose, a jet of water would shoot straight up in the air.

The ARTESIAN WELLS you've probably heard of are wells drilled into a confined aquifer. The water level in artesian wells rises ABOVE the level of the confined aquifer. Sometimes there is enough pressure in an artesian well to push the water above the surface of the ground. Then it's called a FLOWING ARTESIAN WELL. That's the kind you usually see pictures of.



Pressure in a confined aquifer may push well water above the ground surface, but water from a shallow well in an unconfined aquifer will have to be pumped out.

Unit 3: What's in the Groundwater?

Now you know where groundwater is and how it moves from place to place.

All the moving around that groundwater does means that other substances can move through the ground, too.

THIS PART'S IMPORTANT: As groundwater moves through the earth, it takes with it all sorts of things.

Some of groundwater's travelling companions (such as bacteria and viruses) may make us sick. Some (such as minerals) may make the water taste awful. And some (like industrial pollutants) may be long-term health hazards.

Good grief! How do all these things get into OUR groundwater?

They come from all over the place. Some occur naturally, but there are lots of man-made sources, too: faulty septic tanks or sewer systems; overly enthusiastic fertilizing of farms, lawns, and gardens; animal manures; chemicals dumped by industries; leaking oil tanks; landfills and garbage dumps; mining processes. . . .

First the ones that occur without the help of mankind: groundwater picks up some substances just by filtering through the ground. Water dissolves calcium, iron, sodium, fluorine, manganese, magnesium, sulfur — among other elements — out of the rocks it flows through.

DEMONSTRATION 3: GROUNDWATER ACIDITY

PURPOSE: To observe how the decay of vegetation affects the acidity of groundwater

MATERIALS: stream table or box with garbage bag liner
sand
water
watering can or plant mister
food
pH paper

PROCEDURE: If you don't have access to a stream table, line a sturdy cardboard box with a plastic garbage bag. Punch a hole in one corner of the box (and liner) for water to drain through.

Fill the box with sand. Place some food in the sand (you could use something from a fast food place, or from the school cafeteria). Stir the food and sand so that half of the food is under the sand and half is above "ground."

Tilt the box slightly so that the drainhole is the lowest point. (Prop up the highest corner.) Water the food and sand daily. Collect the water draining out of the box and test it with pH paper each day. Continue until the food is mostly gone.

Record pH level for every day.

CONCLUSION: As the food decomposes, the acid level rises. Water percolating through the decomposing food picks up acids and leaches them into the water you collected for testing.

DISCUSSION: Decaying plant matter in the soil undergoes the same process. The change in the water's acidity changes the water's ability to dissolve some rocks and minerals (like limestone) underground.

QUESTIONS:

1. What does the decaying food represent in a natural (earth) system?
2. What connection was there between the decaying of the food and the change in the pH level of the water that had drained through the box?
3. Could changes in seasons cause differences in the level of groundwater acidity?
4. Collect some water samples from various sources (well water, water from a municipal water system, water from a creek, water from a mud puddle, rainwater). Test the pH level of each. Why do they have different levels?

DEMONSTRATION 4: LEACHING

PURPOSE: To show how groundwater dissolves soluble materials and carries them through the earth

MATERIALS:

sand	cornstarch
salt	lead chloride
iodine	toothpicks
water	paper cups

PROCEDURE: This demonstration will use three different mixtures: sand, sand + salt (the more salt, the better the reaction), and sand + cornstarch. For each student or group taking part, figure 2/3 of a cup of each mixture.

Each student or group will need two paper cups. Punch several holes in the bottom of one cup. Fill the cup 2/3 full with the first "mixture" (sand only). Insert four toothpicks into the sand-filled cup on four sides so that the toothpicks extend into the sand about 1/2 inch below the sand line. The toothpicks will be used to support this cup over the second cup, into which liquid (leachate) will drain from the sand cup.

Put the sand cup in place over the other cup. Now fill the sand cup to the rim with water. Continue adding water to the draining sand until the bottom cup is 1/3 full of "leachate."

Has the water changed? To check, add a few drops of iodine to the leachate in the second cup. Record any changes. Then add a few drops of the lead chloride. Observe the results. Record any changes.

Clean the cups and repeat the process with the other two mixtures (sand + salt, sand + cornstarch).

RESULTS:

IODINE REACTION:

sand only leachate = _____

sand + salt leachate = _____

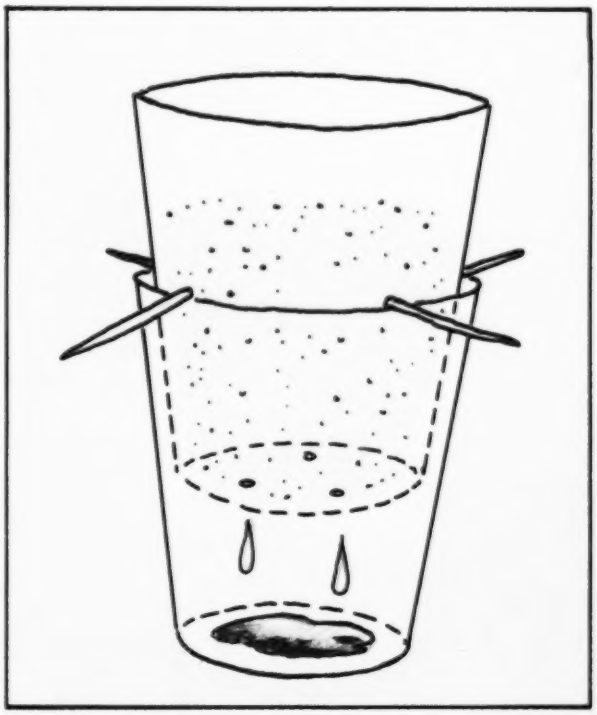
sand + cornstarch leachate = _____

LEAD CHLORIDE REACTION:

sand only leachate = _____

sand + salt leachate = _____

sand + cornstarch leachate = _____



CONCLUSION: As the water passed through the sand, it dissolved any water-soluble materials it came in contact with. As the water dripped out the bottom of the sand cup, it carried with it those dissolved materials. The process of picking up and transporting soluble substances is called LEACHING.

One point this demonstration makes well is that you cannot always tell just from looking at water whether or not there are dissolved chemicals in it (in this demonstration, the dissolved chemicals were the salt and cornstarch). The same holds true for toxic substances that may leach into our groundwater: there may not be any obvious smell or visual clue to their presence.

QUESTIONS:

1. What natural activity is represented by pouring water over the mixtures?
2. Groundwater can leach minerals out of rocks as well as leaching out substances that might not have occurred in the ground naturally. What might the salt and cornstarch represent?
3. Does a material have to be buried or thoroughly mixed with the sand (or ground) to contribute to leachate? How else might materials leach into groundwater?

Calcium dissolved out of limestone, for example, makes water "hard"; soap doesn't get very sudsy, and thick white deposits accumulate on pots and pans and water heaters. But the hard water tastes a lot better than groundwater with dissolved iron in it, a problem that can occur with just about any kind of rock because so many rocks contain iron.

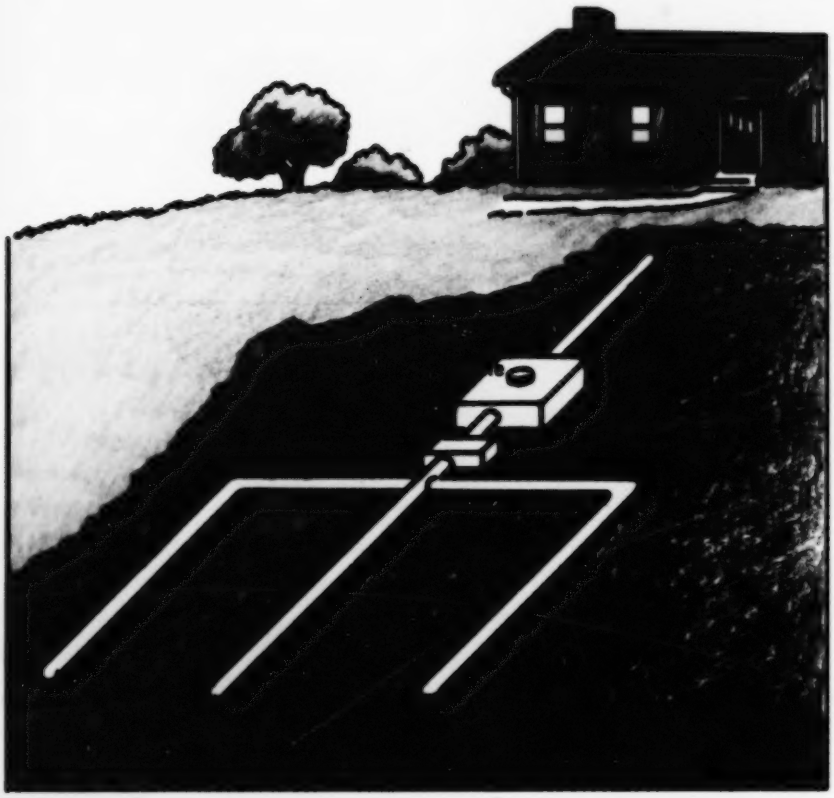
What kinds of minerals are in groundwater will depend on what kinds of rocks there are in the area. How much of some mineral the groundwater has depends mostly on how long the water was in contact with the rock. The longer the contact, the more chance groundwater has to dissolve out a mineral.

But a lot of the contaminants in our groundwater are there because of people.

One very common groundwater problem in Virginia comes from untreated sewage (what you flush down the toilet) leaking into the ground. It comes from damaged sewer lines or from septic tanks that aren't working quite the way they should.

Those of us who live in towns or cities usually depend on municipal water and sewer systems. But rural families often live too far away from town to hook up to those systems. Instead, they have their own water supplies (wells) and sewage treatment (septic tank systems).

septic system



Cutaway view of a typical septic system.

With a septic tank system, household wastes are piped to an underground tank, where bacteria decompose some of the solid wastes. Wastewater flows out of the tank into an underground drainfield.

Soil has the ability to cleanse wastewater of its bacteria and viruses. If wastewater filters through enough soil, eventually it will become clean again, safe enough to drink. And that's good, because eventually, after it's made its way into the saturated zone and into an aquifer, it may again end up in someone's water supply.

That's if everything works the way it's supposed to. If some of the drainfield pipes clog, wastewater is forced through the unclogged pipes, causing only a small area of the drainfield to accept the load of water intended for the entire field. When that happens, contaminated water may ooze up to the surface where it can be a health hazard to people and animals.

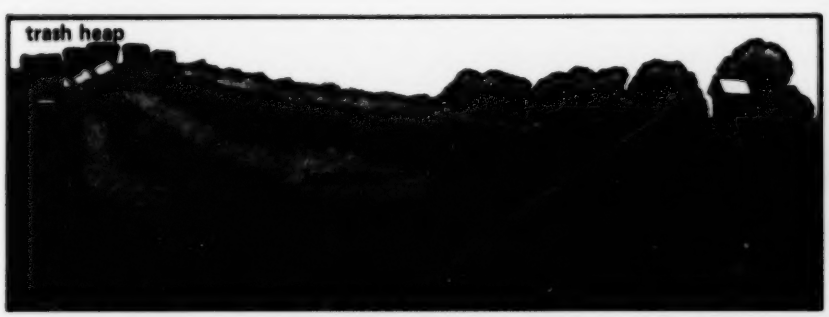
Or the drainfield might be located in ground that doesn't give the wastewater a chance to filter through enough soil to get clean. If the wastewater flows into fractured crystalline rocks, for example, it may move too quickly through the rocks to be cleansed. The unhealthy water may end up right back in the family well or in nearby streams, or it might carry its pesty little contaminants great distances to unsuspecting users somewhere else.

toxic materials

Sewage isn't the only problem groundwater has because of our household plumbing. Many people don't realize they may be polluting groundwater when they get rid of TOXIC MATERIALS — like paint thinner or insecticides — by pouring them down the sink or flushing them down the toilet.

"Toxic" means that a substance can be dangerous enough to make people or animals very sick or even kill them. Many toxic substances don't break down in the soil; they can travel with the water right into the saturated zone and into the aquifer, just as toxic as they were when they got poured down the drain.

Even when we don't pour them down the drain, some of these toxic household chemicals end up in our groundwater. When we throw old bug spray containers, or varnish cans, or other toxic materials in the trash can, they get hauled off with the rest of the garbage. Ever wonder where all that trash ends up?



Leachate may travel through soil and rocks as a contamination plume.

landfill

It is usually dumped into a LANDFILL, a piece of land the town or county has set aside for that purpose. Newer landfills are often called SANITARY LANDFILLS because the garbage is compacted (squashed), then covered with dirt or clay, to cut down on health and safety risks to the public.

Many old landfills were built before we had any idea they might cause trouble for groundwater. All sorts of trash — including poisonous household chemicals — were dumped into them. The problem was that nothing kept rainwater from percolating (filtering) down through them. . . .

Suppose an old landfill was located where water travelled easily through the soil and rock layers. Now suppose some of the trash in the landfill includes water-soluble toxic chemicals. Rainwater dripping down through the landfill might dissolve out some of those chemicals and carry them into the groundwater.

It's like brewing a pot of coffee. Water dripping through the coffee grounds picks up the soluble parts — the flavor and color — of the ground-up coffee beans.

leachate

When water filtering through a landfill performs a similar trick, the resulting liquid is called LEACHATE. Leachate is the groundwater equivalent of a cup of coffee — except that no one wants it, and it may continue on into an aquifer used as someone's water supply.

Newer landfills are generally located where the rock layers won't let leachate reach the water table. In other words, the landfills are designed above an impermeable rock or clay layer which water can't filter through. A small amount of leachate may eventually leak (very, very slowly) through clay, but the clay itself will filter many of the contaminants out of the leachate.

DEMONSTRATION 5: LANDFILLS

PURPOSE: To investigate effects of improperly constructed landfills

MATERIALS: stream table or box with garbage bag liner
sand
potassium permanganate
water
garden watering can or plant mister

PROCEDURE: If you don't have access to a stream table, line a sturdy cardboard box with a plastic garbage bag. Punch a hole in one corner of the box (and liner) for water to drain through. Tilt the box slightly to encourage drainage toward the hole.

Fill the box with sand. Scoop out a small "landfill" area and fill the hole with potassium permanganate. Cover the "landfill" with sand. Sprinkle water over the entire area. Repeat daily, observing carefully the water that drains from the box.

RESULTS: The water has taken on a purplish color.

CONCLUSION: Liquid wastes and water-soluble materials placed in landfills may leach out of the landfill, particularly if the landfill is an old one. Newer landfills are generally located and constructed so that there is an impermeable layer of materials (clay, concrete, or plastic liners) at the bottom to keep as much leachate as possible from leaving the landfill.

QUESTIONS

1. What sorts of materials are found in real landfills?
2. What could be done to keep water-soluble materials from leaching out of the landfill? Would it help if no water (including rain) ever got into the landfill? What could be done to keep the landfill contents from getting wet?
3. In a real-life setting, where might the leachate end up?
4. What are the similarities between landfills and trash heaps or roadside dumps?

(But even if we fixed all our old landfills so they wouldn't leak leachate into aquifers, we've still got private dumps and trash heaps in our woods and highways. Goodness only knows what is leaking out of them. Even if they are smaller, they pose the same kind of threat to groundwater as the landfills.)

hazardous waste sites

Not all landfills are hazardous. But several landfills and dumps are among the possible HAZARDOUS WASTE SITES that the Environmental Protection Agency (EPA) has listed in Virginia.

"Hazardous wastes" are chemical substances that are harmful to humans and other animals. Some hazardous wastes include common toxic or poisonous household products. Others might be industrial wastes, buried in drums or leaking out of waste ponds or lagoons where companies had been dumping chemicals for years.

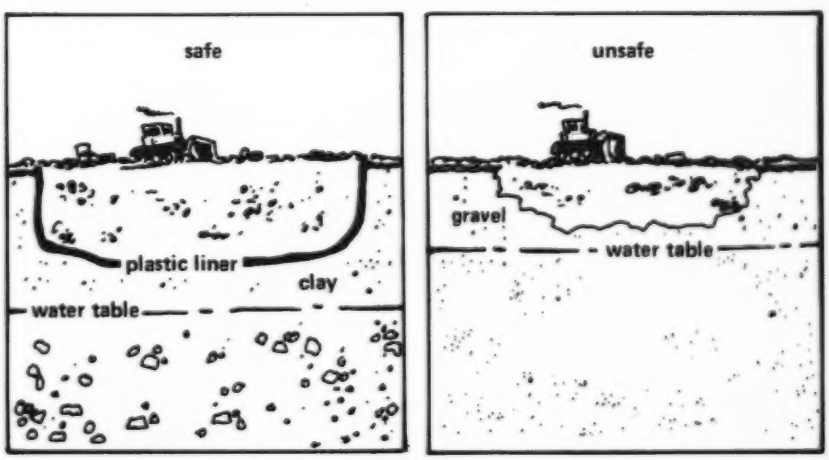
By the spring of 1986, EPA had listed over 350 sites in Virginia that need checking for hazardous wastes that could be polluting our groundwater.

leaking storage tanks

Several of the sites on EPA's list are there because of a growing and serious problem which we're just starting to recognize. Gasoline and oil tanks buried underground — all over Virginia — have been leaking petroleum products into the soil and eventually the groundwater. And the problem is getting worse.

Gasoline storage tanks at service stations are one kind of buried tank. Heating oil for home furnaces may be buried in tanks outside a house, too. Many of those tanks, old and corroded (eaten away) by acids naturally present in the ground, are now leaking petroleum products (such as gasoline and oil) into the soil. Each year the Virginia Water Control Board gets more and more complaints — about 100 in 1985 — about groundwater which has been contaminated by storage tank leaks.

There's another way that petroleum products find their way into our groundwater. Lots of people who change the oil in their cars just carelessly dump the used oil on the ground or down storm drains . . . where it can find its way fairly easily into surface waters and groundwater.



New landfills are designed to prevent leachate from leaving the landfill. Older landfills may have no protective barriers.

Some regions in Virginia have their own special problems. Where farming is common, there may be a problem with fertilizers, pesticides, and herbicides (weed and bug killers) sneaking into the groundwater. The pesticides and insecticides usually have toxic chemicals in them, like the hazardous wastes mentioned earlier.

The fertilizer is a little different story. When we put too much fertilizer on a field or garden, excess nitrates (a form of nitrogen used in fertilizers) get into the water system. Nitrates in our water may cause diarrhea in humans and several illnesses in cattle. Nitrates also are suspected of reacting in the human stomach to produce nitrosamines, some of which might be carcinogenic (cancer-causing).

nitrates

Nitrate contamination can also come from piles of animal manure on farms. This nitrate problem doesn't affect such broad areas as repeated over-fertilizing, but nitrates from animal manure may cause more acute problems in a small area.

Those areas where coal is mined have another problem. Coal seams almost always have some pyrite in them. Pyrite is the mineral most of us call "fool's gold." Pyrite has sulfur in it. When coal is mined or exposed to air, the pyrite oxidizes (combines with the oxygen) and the sulfur in the pyrite forms sulfuric acid. The groundwater problem occurs if the sulfuric acid drains into our groundwater and streams. The problem is called ACID MINE DRAINAGE.

acid mine drainage

SUPERFUND SITES

The Environmental Protection Agency (EPA) is looking at over 350 sites in Virginia which contain materials that MIGHT be polluting our air or water. At least that's the number they were looking at as of January 1986. The number may change as new places are considered or old ones are cleared.

Some of these places are landfills or dumps; some are mines and rock quarries; and some are locations of chemical spills and other accidents.

Not all of those places will turn out to be hazards, but we know already that four of them are serious. The EPA has listed them in its "national priorities list," which means that they need to be cleaned up immediately.

"Hazardous wastes" can be a wide range of substances. One school workbook, *A-Way With Wastes* (from the Washington State Department of Ecology), defines "hazardous wastes" as "those wastes which provide special problems to living creatures or the environment because they are (a) poisonous, (b) explosive, (c) attackers or dissolvers of flesh or metal, (d) readily burnable — with or without a flame, (e) carriers of disease, or (f) radioactive. Some wastes cause only one problem. Others combine several of the above."

The four worst sites in Virginia are in Nelson, Roanoke, Smyth and York counties.

In Roanoke County, chromium (a metallic element) from an electroplating process has made its way into the groundwater. In York County, a metallic element called vanadium contaminated the groundwater after fly ash, a waste product from burning fuel, was buried in pits.

Large populations of fish were killed in the Piney and Tye rivers when an industrial plant in Nelson County dumped 80,000 tons of copperas wastes on a hillside. The copperas, a by-product of a mining operation, produced an acidic runoff which was fatal to the fish. And mercury contamination from waste disposal ponds in Smyth County has made fish from the North Fork of the Holston River unsafe to eat since 1970.

Besides these four, another eight Virginia sites are being considered for the national priorities list. These eight are Culpeper Wood Preservers (Culpeper), IBM-Manassas (Manassas), Avtex Fibers (Front Royal), L.A. Clarke & Sons (Spotsylvania), Rhinehart Tire Fire Dump (Frederick), Defense General Supply Center (Chesterfield), Love's Container Service (Buckingham), and First Piedmont Rock Quarry (Pittsylvania).

Uranium ore is responsible for another possible groundwater problem in some parts of Virginia. Groundwater in contact with uranium-rich rocks will pick up some amount of radon (a radioactive gas) just from contact with the rock. Mining activities can make the problem worse.

radioactive waste

Mining and milling processes used to recover uranium ore produce not only the uranium but also tons and tons of crushed waste rock (tailings). Because the uranium is radioactive, the waste rock is a form of low level radioactive waste, too. Rainwater dripping through the tailings can leach out radium 226. We don't really know what safe levels are for radioactive elements in our drinking water. If enough leachate reaches the groundwater, then the water may no longer be safe to drink.

Small amounts of radioactive wastes are also produced by biological laboratories and hospitals. There's not much chance that these wastes will be leached out by rainwater, but they do need to be disposed of carefully, too.

Unit 4: Virginia's Regions

Okay. First you learned where groundwater is. Then you learned how it moves through different rock layers. And now you know about pollutants. Time to put them all together. Time to find out what happens in YOUR area of Virginia.

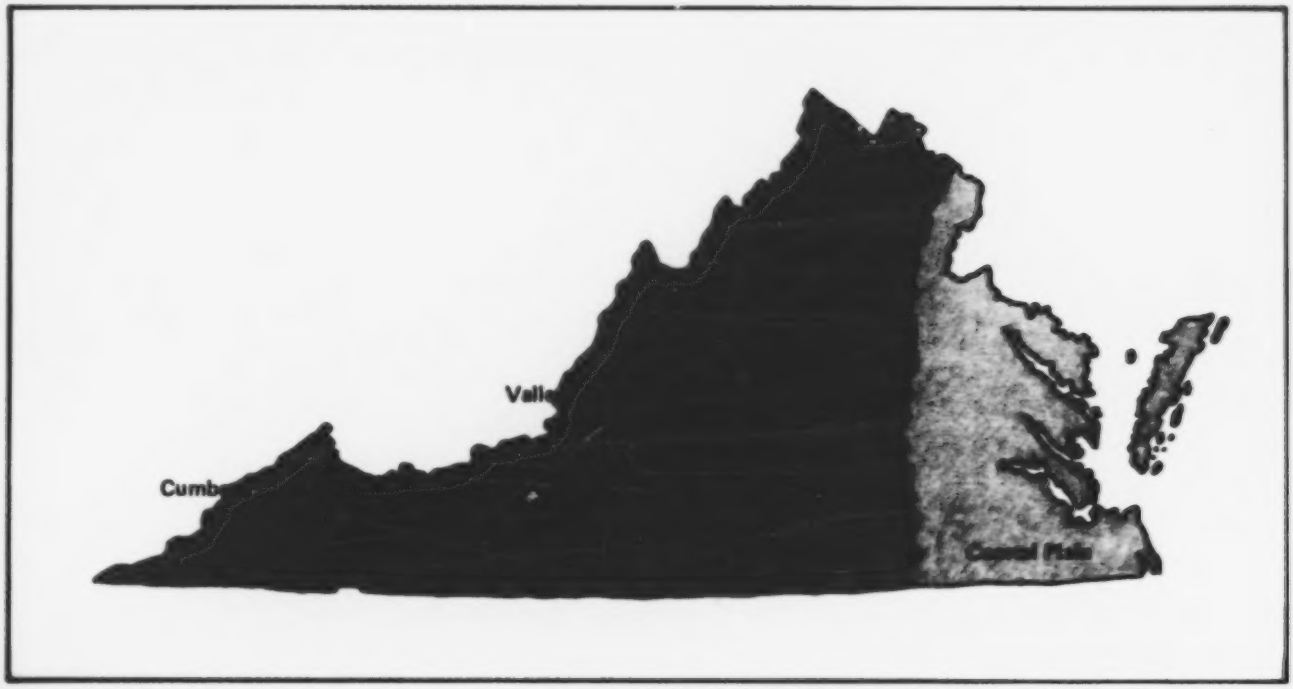
It would be easier if Virginia's rocks and rock layers were the same all across the state. They aren't. Virginia has five main geologic regions (sometimes called provinces). The map below gives a general indication of the extent of each region. (More detailed maps are available from two state agencies. A geologic map of Virginia is available from the Department of Mines, Minerals and Energy. A groundwater map can be obtained from the Virginia Water Control Board.)

Remember the major kinds of deposits that aquifers are found in — the unconsolidated (like gravel), the sedimentary (like sandstone and limestone), and the crystalline (like granite)? Each of Virginia's regions has a distinctive set of rocks, mostly falling in one of those three categories.

The Coastal Plain is mostly unconsolidated deposits; the Piedmont, crystalline; the Blue Ridge, crystalline and sedimentary; the Valley and Ridge, mostly sedimentary; and the Cumberland Plateau, sedimentary.

COASTAL PLAIN

The coastal plain's deposits are mostly sand, gravel, silt and clay. Shallow (near the surface) aquifers in the sands and gravels lie on top of the clay layers. Clay is relatively impermeable (the water can't easily soak down through it) so water collects on top of the clay, in deposits of sand or gravel.



Virginia's five regions are, from west to east, the Cumberland Plateau, Valley and Ridge, Blue Ridge, Piedmont, and Coastal Plain.

BUT — water which filters only through sand or gravel doesn't have much chance to get rid of unwanted tag-alongs. If the water goes in polluted, it comes out that way, too.

The Coastal Plain also has sand and gravel aquifers caught beneath the clay beds. Those aquifers are called confined aquifers because the water in them is sandwiched between two impermeable layers (here, the impermeable layers are clay). These confined aquifers are the main sources of groundwater for Coastal Plain users.

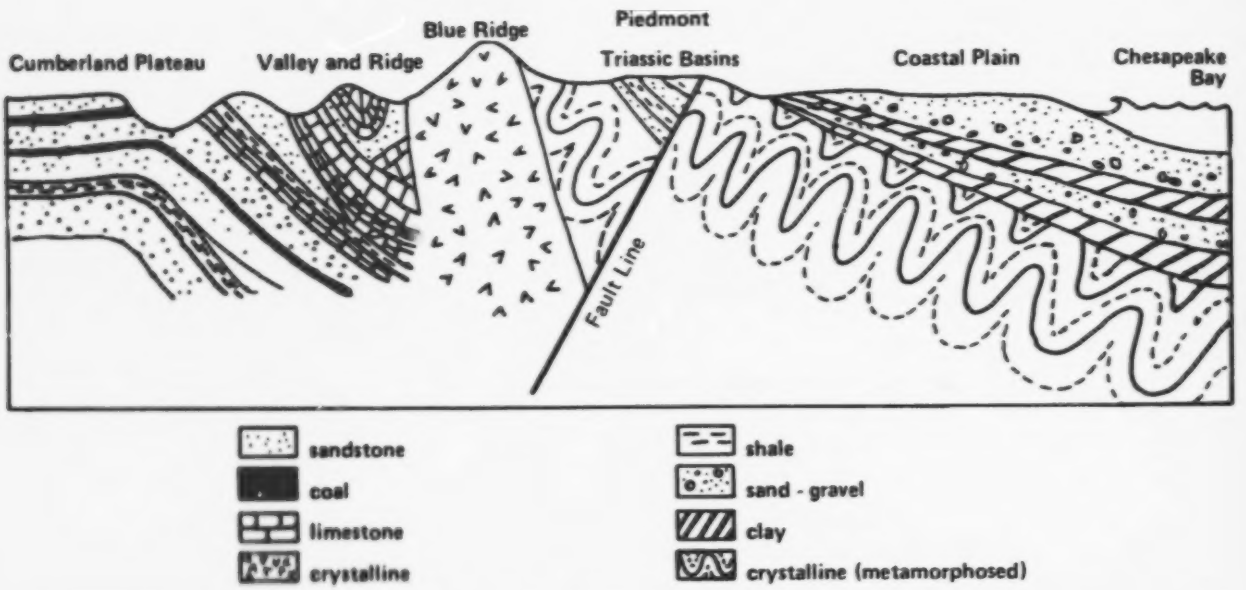
The good points about these confined aquifers are: they have higher yields (you can get more gallons per minute out of them) than the shallow aquifers do; and the quality may be better because the water is protected from surface contamination by the overlying clay layer.

The bad points are: it costs more to drill wells into deeper aquifers; and deeper water may have too many dissolved minerals and salts to be drinkable. You're particularly likely to hit salty water in a deep aquifer if you're near the coast.

THE PIEDMONT

The Piedmont's rock strata are mostly crystalline rocks like granite and gneiss (pronounced: "nice"), in which the only useful water passages tend to be in fractures and faults (cracks). Because there are fewer and smaller water-bearing fractures the deeper you go, the only really useful supplies of water are found within a few hundred feet of the surface.

Unlike many other areas in Virginia, the Piedmont has a generous soil layer overlying its fractured crystalline rocks. Wells in the Piedmont are often shallow



Simplified cross-section of Virginia shows the five provinces: Cumberland Plateau, Valley and Ridge, Blue Ridge, Piedmont (including Triassic Basins), and Coastal Plain. (Used by permission of Lyle Silka, Hydrosystems, Inc.)

— less than 75 feet deep — and the water quality tends to be very good because of the overlying soil layer. (Good, that is, except where the water has been contaminated because of human activities.)

The Piedmont also has some curious areas called Triassic Basins (Triassic refers to the age of geologic history during which the basins were formed — about 200 million years ago, when dinosaurs roamed the earth). The Triassic Basins are sandstone and shale with some crystalline intrusions (rocks that were injected — while they were still hot and melted — into the sedimentary rocks that were already there. After the intrusions cooled, they hardened and crystallized.)

The sandstones of the Triassic Basins are good quality aquifers, but deeper aquifers and those near the crystalline intrusions yield poorer quality water.

BLUE RIDGE

In the middle of the state is a narrow region called the Blue Ridge. It has the highest mountains in the state, but the rocks on the eastern flanks are different from the rocks on the western flanks of the mountains. On the eastern side, the rocks are mostly crystalline. The only source of water here is — you guessed it — in the fractures and faults.

GROUNDWATER IN VIRGINIA

Adapted from "Groundwater Map of Virginia," Virginia Water Control Board, 1985

Cumberland Plateau
- nearly flat-lying sedimentary rocks
- small to moderate supplies available
- generally poor quality water
- moderate pollution potential

Piedmont
- crystalline rocks (except sedimentary in Triassic Basins)
- small to moderate supplies available
- generally good quality in crystalline
- moderate to low pollution potential

Blue Ridge
- crystalline rocks (eastern side)/sedimentary rocks (western side)
- small supplies available
- generally good quality
- moderate pollution potential

Coastal Plain
- unconsolidated layered sediments
- very large supplies available
- generally good quality
- moderate pollution potential; high pollution potential in shallow aquifers

Valley and Ridge
- folded, faulted sedimentary rocks
- moderate to high yields
- quality varies: good in quartzites, hard in carbonates (like limestone), poor in shales (sedimentary)
- pollution potential varies: low in folded sedimentary except along faults, moderate in shales, high in areas with solution cavities and sinkholes

But on the western slopes, the rocks are sedimentary (like sandstones and limestones), through which water travels down fairly easily to the lower slopes. Water moves through these rocks not only through their pores spaces and solution channels but through fractures (from mountain building) as well.

VALLEY AND RIDGE

The Valley and Ridge area is underlain mostly by limestone, dolomite (a cousin of limestone), sandstone, shale (a rock made from clay), and conglomerates.

Conglomerates are rocks made from pebbles and chunks of old, broken rocks, all now held together by natural cements. Because conglomerates are made of pieces of earlier rocks, they can have any kinds of rocks or minerals in them.

The Valley and Ridge area has only a thin soil layer, so there's not much of a filtering system to clean water before it reaches the water table.

The limestone and dolomite are found largely in the valleys. They have very productive aquifers in them. The limestone is so soluble (easily dissolved) that in many places in this region, the limestone layer has partly or completely dissolved away, leaving caves and sinkholes (where the earth has caved in).

DEMONSTRATION 6: SINKHOLES AND CAVES

PURPOSE: To demonstrate how sinkholes and caves form

MATERIALS: stream table or box lined with a plastic garbage bag
sand
sugar
water
plant mister or garden watering can

PROCEDURE: If you don't have access to a stream table, line a heavy cardboard box with a plastic garbage bag. Punch a hole in one corner of the box (and liner) for water to drain through.

Fill the box with sand. Dig out a hole 5"-10" wide (depending on the size of your box) and 3"-5" deep. Pour in enough sugar to nearly fill the hole (leave about 1/2" to 1"). Fill in the last 1/2" to 1" with sand, so that the sugar deposit is buried.

Using a watering can or a plant mister, water the box of sand. Use enough water to saturate the top few inches of the sand, but be very careful not to disturb the surface. (You must water the sand gently, or the force of the water will rearrange your sand and sugar deposits. Be sure not to pour the water from too high above the sand and do not pour in one place too long.)

Tilt the box (prop something under the high corner) so that the water drains toward the corner with the hole.

"Rain" on the sand once a day until the sand begins to sink where the sugar deposit is buried. Once the subsidence (sinking) begins, continue the daily watering process but use a smaller amount of water.

RESULTS: Where there once was flat sand (above the buried sugar), there is now a depression.

CONCLUSION: As the water leached away the sugar, increasingly large spaces were left empty. Eventually there were so many "solution channels" or empty spaces that the overlying sand layer could not be supported. When the sand finally collapsed, a sinkhole was formed.

Limestone is a rock easily dissolved by groundwater. The dissolution of limestone by groundwater over many thousands of years creates the sinkholes and caves which are abundant in the limestone regions of Virginia.

QUESTIONS:
1. What natural process does the watering represent?
2. What rock might the sugar represent?
3. What characteristics must a rock have to be suitable for forming sinkholes and caverns?
4. Why did the sinkhole form only over the sugar deposit?

One problem here is that people for years and years have used sinkholes to dump garbage in — out of sight, out of mind, but also, unfortunately, into the groundwater system that carved out the sinkhole in the first place.

Rainfall in limestone areas can also carry pollutants — like animal manure, fertilizers and pesticides — into sinkholes. The water flowing through a sinkhole (or any kind of cave, for that matter) may finally come out at a spring, possibly one used as a someone's water supply.

Stalactites hang from the cave ceiling; stalagmites build up from the floor.

CAVES

One of the things rainwater does when it begins trickling down through ground is to dissolve carbon dioxide from dead plants in the soil. The water and the carbon dioxide team up to produce carbonic acid (H_2CO_3). Result: the rainwater — now groundwater — becomes weakly acidic.

Acidic groundwater has quite an effect on a rock called limestone: it dissolves it.

Not all at once, of course. But little by little, the water carries away traces of the limestone, a rock which is based on the mineral calcite ($CaCO_3$: calcium carbonate).

The dissolving process begins in the limestone's cracks and fractures. As the water carries away more and more of the limestone's calcite, the cracks get bigger. In several hundred thousand years, enough limestone may have dissolved away so that great gaping caverns are left hidden under the ground.

Scientists think that most of the dissolving-away process takes place at whatever level the water table is at the time. But cave formations like stalactites and stalagmites (stalactites hang from the cave ceiling; stalagmites project upward from the floor) can't form until the cave passage is above the water table, no longer in the saturated zone. They must wait until the cavern itself has formed and the water table has dropped.

The fantasy-like formations begin as single drops of water on the ceiling or wall of a cave room. Just like the water that dissolved and carried away limestone to create the cave in the first place, the water droplet clinging to the cave ceiling has dissolved calcite in it, too.

When the calcite-laden water drop enters the cave air, some of the CO_2 from the calcite and acidic water ($CaCO_3$ and H_2CO_3) diffuses back into the air. With its chemical balance changed, the water droplet gives up some of its calcite. It deposits it in a tiny ring on the cave ceiling.

Each water droplet deposits a trace more calcite at the tip of the one before it. Eventually a delicate, hollow tube is formed. The young formation is called a "soda straw."

Over the years, the calcite layers build up, sometimes to astonishing thicknesses. Sometimes they form the familiar stalactites and stalagmites we've all seen pictures of. Sometimes they form more fantastical shapes: delicate miniature dams holding tiny pools of water, or cobble-shaped "flowstones" that look like they're still in motion.

Although the valleys are usually limestone and dolomite, the higher elevations are often sandstone and shale, which yield only enough water for rural supplies.

The Valley and Ridge area is full of fault zones, huge cracks that formed when the mountains were being built. The fault zones have the highest yields in this province, but they are also the most likely to be polluted, because the water in them doesn't have much chance to filter through soil.

CUMBERLAND PLATEAU

West of the Valley and Ridge is a province called the Cumberland Plateau. It's underlain by sandstone, shale, and coal.

The coal may be great for the area's economy but it can be very hard on the quality of the groundwater. Because coal releases some unwelcome elements (sulfate, sulfite, and iron) into the groundwater, groundwater within the first 100 feet of rock below stream level isn't usable. The best water seems to come from bedrock above stream level.

Unit 5: What We Can Do To Help

Groundwater faces a lot of different problems, such as hazardous wastes buried in old landfills, leaking storage tanks, faulty septic systems, overused pesticides and fertilizers, and industrial chemicals leaking out of disposal ponds.

But groundwater also faces some threats that we can help prevent. Here's what you can do:

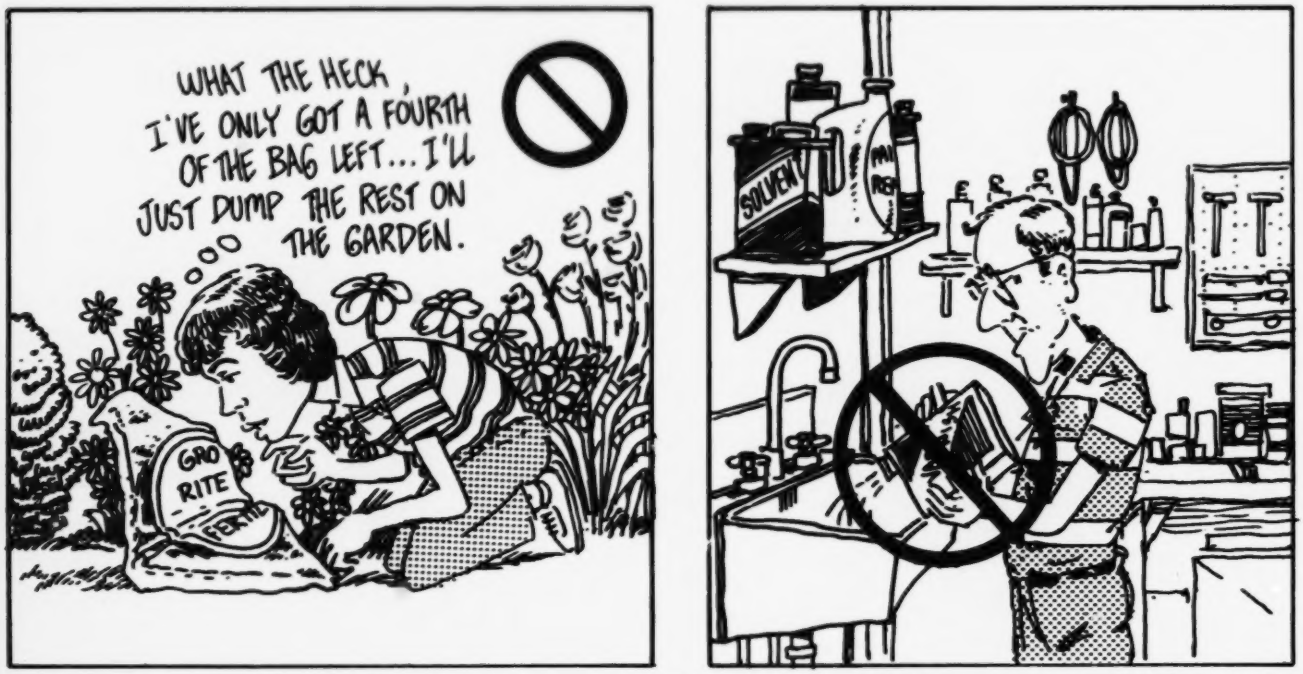
★ Don't pour any toxic or hazardous substances (including paints, varnishes, thinners, waste oils, pesticides and herbicides) down the drain or into the toilet.

★ If you change the oil in a car, take the time to find an oil collection center (at service stations) near you. That oil can be recycled. And if the oil is recycled, that means it won't end up in our groundwater. To find a collection center near you, call this toll-free number: 1-800-552-3831.

★ Don't dump anything down a sinkhole!

★ When you use fertilizers or pesticides, follow the directions. When you're through with the product, read the label again to see how to dispose of the container. Some of these products can be toxic, so you have to be careful how you throw away the containers. If the label doesn't tell you the proper way to get rid of the container, ask your local extension office or health department.

★ For anyone with wells: Be very careful what you store near a well. Don't store fertilizers, pesticides, oil, gasoline, or diesel fuel within 20 feet of a well. Don't even use fertilizers and pesticides within 20 feet of a well. Don't dump any kind of wastes near a well. And don't build livestock pens or barns near a well.



Use only the amount of pesticide or fertilizer recommended by the product label; overuse can contaminate water supplies. And never dump toxic substances into household plumbing. They can pass through a septic system or sewage treatment plant and contaminate water supplies.

Cover your well with a cap to keep unwanted items out. Slope the soil around the well so that rainwater or other surface water runs away from the well.

And for anyone with an abandoned well: You can ask the Virginia Water Control Board how to fill in and plug the abandoned well properly. If you don't plug it, surface water (and contaminants) can flow down the well and enter the groundwater directly. Don't throw any kind of wastes — liquid or solid — in an abandoned well for the same reason.

★ For anyone with septic tanks: have your tank pumped out regularly so your system doesn't get clogged. Spread throughout the week those household chores (such as washing clothes) that use a lot of water. Otherwise, your system may not be able to handle that much wastewater.

★ If you know about an illegal dump that may contain hazardous wastes, call the State Department of Health's toll-free hotline at 1-800-552-2075 to report it.

★ And last but just as important: give water conservation a try. The less water we use, the less that has to be cleaned up before it is available again. Install water-saving devices like flow restrictors in faucets. Take shorter showers. Fix dripping faucets and leaking toilets. Make sure the dishwasher and the clothes washer are full before you run a load. Don't leave the water running while you wash the car or handwash dishes or brush your teeth.

It's true that there are no easy answers to keeping our groundwater safe and pure. If we're going to have enough clean water for drinking and for indoor bathrooms and for agriculture and for manufacturing and for recreation, then we better start taking care of it right now. We have to understand what groundwater is, where it's been, and what we've done that might affect it.

You know at least some of those things. But most importantly, you know that groundwater needs to be taken care of. And you know how to do that part.

GLOSSARY

ACID MINE DRAINAGE: a potential groundwater pollutant formed when a mineral (pyrite) in coal seams is exposed to air and water and produces sulfuric acid

AQUIFER: an underground rock zone or soil layer that contains usable amounts of groundwater

CONE OF DEPRESSION: the cone-shaped dip in the water table around a well

CONFINED AQUIFER: a water-yielding layer of rock or sand trapped between two impermeable rock layers (layers through which water can't move)

CONGLOMERATE ROCKS: rocks made from pebbles and chunks of older rocks, now held together by natural cements

CRYSTALLINE ROCKS: rocks made of tightly interlocked crystals

DISCHARGE: any of the ways that groundwater comes back out to the surface — springs, creeks, being pumped from a well, etc.

FAULT: a rock fracture in which one or both sides of the broken rock have been displaced (shifted from the original position). Groundwater moves very rapidly through faults

FRACTURE: a crack in a rock. Groundwater can travel quickly through rock fractures

GROUNDWATER: water under the surface of the earth

HAZARDOUS WASTE SITE: a place where harmful materials have been dumped, spilled, leaked, or buried

HOT SPRINGS: groundwater heated by very deep rocks before coming back out to the ground's surface as a spring

HYDROLOGIC CYCLE: the way the earth recycles water from the atmosphere down to (and through) the earth and back to the atmosphere again

IMPERMEABLE: refers to rock and soil layers through which water cannot move

LANDFILL: the site where a city or county dumps its trash

LEACHATE: liquid that has dripped through dumps or landfills, carrying with it dissolved substances from the waste materials

OVERWITHDRAWAL: pumping out too much groundwater

PERCHED WATER TABLE: a source of water trapped above the saturated zone because it has reached a layer through which it cannot soak

PERCOLATE: to filter or ooze through a porous material

PERMEABLE: refers to materials (such as rocks) through which water can move

POROUS: refers to materials which have enough open spaces for water to move through

RECHARGE: water coming into the groundwater system, such as rain soaking into the ground

SALTWATER INTRUSION: when salty water mixes with fresh groundwater near the seacoast, usually because too much of the fresh water has been pumped out

SATURATED ZONE: the area below the water table where open spaces are filled with water

SEDIMENTARY ROCKS: rocks made from compressed sediments (such as sand)

SEPTIC SYSTEM: a sewage treatment system used by families whose homes are not connected to municipal sewer systems. Septic systems have underground tanks which decompose some of the waste and a connected underground drainfield through which liquid wastes pass into the soil

SINKHOLE: a depression common in limestone areas, where limestone dissolves and the overlying ground collapses

SPRING: groundwater seeping out of the earth where the water table intersects the ground surface

SUBSIDENCE: land collapse due to overwithdrawal of groundwater (or to groundwater dissolving out limestone layers which had previously supported the overlying soil)

TOXIC MATERIALS: substances that can make people and other animals very sick, maybe even to the point of death

UNCONSOLIDATED DEPOSITS: loose layers such as sand and gravel

UNSATURATED ZONE: the area between the ground surface and water table. Also called "zone of aeration"

WATER TABLE: the top surface of the saturated zone

Virginia Water Resources Research Center
Virginia Polytechnic Institute and State University
617 North Main Street
Blacksburg, Virginia 24060-3397
Phone (703) 961-5624